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THE HORIZONTAL CURVED GEOMETRIC DESIGN WITH AUTOCAD CIVIL 3D® ON JALAN MUARA WAHAU, EAST KALIMANTAN

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ABSTRACT

Roads connect one area to another. Therefore, an excellent geometric design of the road can reduce the percentage of accidents. For this reason, AutoCAD Civil 3D® is used as a means of planning. This road planning aims to plan the horizontal alignment of the road connecting the main road with kpc Tanjung bara (coal port). This street is located on Jalan Poros Muara Wahau, East Kalimantan. This study used secondary data obtained through google earth and global mapper. Then the data is processed using qualitative research methods. This study found that the road section length was 6,086 m or 6,086 km (STA 0 + 000 – 6 + 086). Bends P1 on (STA 2+680 – 3+260) are planned with the type S-C-S bend. The bend has an R of 600 meters, an e of 4.3%, and a Ls of 119 meters.

INTRODUCTION

Forest roads are the central infrastructure that provides access to forest areas for the sustainable management, protection, and utilization of forest resources. In addition, forest roads also have a role in the world of transportation and the economy. According to theory, forest roads are maintained for two overarching purposes: traffic (specifically to provide economical access to forest resources) and minimizing negative environmental impacts. In Canada, the forest area covers about 361 million ha, and there is conversion of forest functions into Agriculture, Hydroelectric Power Generation, and Oil and gas mining. With all these activities, roads are needed as a means of transportation to distribute materials or produce products. Because an efficient road network has become the backbone of forestry, whose design is based on fundamental principles (Akay, Serin, Sessions, Bilici, & Pak, 2021); (Dodson, 2021); (Government of Canada, 2022); (Heinimann, 2017).

Indonesia is rapidly expanding its economic development corridors on its main islands to promote economic growth (Sloan, Alamgir, Campbell, Setyawati, & Laurance, 2019). Therefore, Indonesia needs road construction as a pillar of economic development because good transportation relations create productive and efficient cities that encourage innovation and economies of scale. The Borneo area of Indonesia supports 37 million hectares of native tropical forests. Many large-scale infrastructure projects that promote land development are planned or are underway in the region (Van Rensburg & Krygsman, 2020); (Alamgir, et al., 2019). In Indonesia, the creation of forest roads is regulated by the Regulation of the Minister of Environment and Forestry, Indonesia Number 8 of 2021 Article 5, namely the Design of Forest Management as

referred to in Article 3 paragraph (2) letter b is carried out by designing the division of blocks within the KPHL or KPHP area and designing the opening of Forest areas for Forest roads, facilities, and infrastructure (Ministry of Environment and Forestry of the Republic of Indonesia, 2021).

Many things need to be considered when designing roads, one of which is geometric road planning. The geometric design of a highway is a road design that deals with the design of the physical features of a visible highway. Road Geometric Planning is part of road planning that focuses on horizontal and vertical alignment to fulfill the primary function of the road, namely providing optimal traffic flow comfort following the planned speed. Alignment is a road route defined as a series of tangents and turns. Incorrect alignment planning can increase the risk of accidents. For example, minimal geometric elements such as very short visibility or sharp horizontal curves result in a much higher accident rate. Certain combinations of elements lead to extraordinarily severe accident problems. Therefore, the geometric design of the road must be done well to reduce the accident rate. This paper will discuss road planning using the AutoCAD Civil 3D® application so that road planning can be more effective. (Veer, Gupte, & Juremalani, 2018) (Paikun, SP, Destaman, & Winardi, 2021) (Veer, Gupte, & Juremalani, 2018) (Gangwa & Deulkar, 2020)

AutoCAD Civil 3D® is a program for planning, designing, and producing project development on the land, water, and transportation. The program can draw designs of roads, highways, sites, and rails. The research uses this program because AutoCAD Civil 3D® can work in a detailed design environment based on 3D (Autodesk Inc., 2022)® models with automation, analysis, and design optimization tools. The program can also automatically produce plans based on already created 3D design models. Although several factors influence the highway's design, the corresponding geometric design aims to provide optimal efficiency in traffic operations with a step of satisfaction safety measures at a reasonable cost (Autodesk Inc., 2022); (Chakole & Wadhai, 2022).

In this paper, geometric planning of horizontal arches with AutoCAD Civil 3D® will be discussed on Jalan Poros Muara Wahau, East Kalimantan. The estuary axis road was chosen because it leads to a coal terminal. So, the road is often used as a means of transportation for coal dump trucks. Coal transport is carried out using dump trucks with a capacity of 30 tons (Yuniar, 2020). Therefore, in this paper, road planning using AutoCAD Civil 3D® will be discussed so that the Muara Wahau Axis Road can be well planned.

LITERATURE REVIEW

Highway

Road transport is part of a more extensive transportation system that includes air, rail, water, and pipeline transport. Highways are the dominant route for most passenger and freight movements. In daily activities, humans are very dependent on the streets. Moreover, land transportation is the transportation most often used by humans. In addition, highways are also very influential in the economic development of a country (Mannering & Washburn, 2020). One proof

of this is from China's Yangtze River Delta region. For the local economy, highway connections can increase their location advantage, attract production factors, and facilitate trade practices, thereby leading to economic growth (Zhang, Hu, & Lin, 2020).

In designing roads, safety is a priority. The safety of road users can be optimized by paying attention to the determination of design speed, which considers the design vehicle and includes the engine strength ratio to the vehicle's weight and driver. Therefore, such roads must first be assigned the function and type of terrain. After these two things are established, the design speed can be determined (Ministry of Public Works and Public Housing of the Republic of Indonesia, 2021).

In addition to safety factors, there are also economic factors. The geometric design of the road, it must be done efficiently but still meet the necessary road service criteria. Through vehicle operating cost planning (BOK), efficiency can be achieved. For efficiency to be achieved, several things need to be considered as an initial identification. They are design criteria, construction costs, vehicle operating costs, and geometric road designs that must consider life cycle costs (Ministry of Public Works and Public Housing of the Republic of Indonesia, 2021).

Another factor that needs to be considered in road design is drainage. Proper drainage is a prerequisite for good pavement management. Insufficient drainage or clogged or damaged drainage facilities will cause inundation, eventually weakening the pavement and accelerating the damage to the pavement. In addition, drainage damage to the highway can cause puddles to form on the road, causing damage to the road. Through visual observations made at STA.0 + 900 to STA.1 + 200 on Jalan Dr. Wahidin Sudirohusodo, it is indicated that the emergence of waterlogging and flooding due to poor road drainage systems can cause road damage (Iskandar, Hadiwardoyo, Sumabrata, & Fitriasari, 2018); (Chairuddin, 2017).

Geometric Roads

Road design is done by deciding how to build a road between two endpoints. Designing roads is complicated since designers must find designs that meet many limitations while minimizing construction costs. The geometric layout of the road has three fundamental parts, namely horizontal alignment, vertical alignment, and cross sections, which after combining, provide a 3-dimensional format for the road. These three factors are continuous to plan a safe road. Geometric roads must be properly planned to reduce the number of accidents. Poorly planned road geometrics can increase the accident rate (Monnet, Hare, & Lucet, 2020); (Gaikawad & Ghodmare, 2020); (Gangwa & Deulkar, 2020).

A vertical alignment (or road profile) is an elongated part of a road, which consists of geometric elements such as curves of peaks and indentations and a gradient (straight slope line) that connects it. In planning vertical alignment, there are several considerations. The profile for vertical alignment depends on topography, horizontal alignment design, design criteria, geology, earthworks, and other economic aspects. So before determining the vertical alignment, the horizontal alignment must be determined first (Raji, Zava, Jirgba, & Osunkunle, 2017); (Ministry of Public Works and Public Housing of the Republic of Indonesia, 2021).

Horizontal alignment is generally a series of arc arches connected without a transitional arch or with an intermediate arch. These arches are a loop of roads connecting straight roads. There are three main factors in horizontal alignment: the number of horizontal intersection points (HPI), their location, and the radius of the horizontal curve. The design of horizontal alignment requires the determination of the minimum curve radius and the length of the curve, as well as the calculation of the horizontal offset from the tangent to the curve to facilitate the placement of the curve in the field (Ministry of Public Works and Public Housing of the Republic of Indonesia, 2021) (Sushma & Maji, 2020) (Raji, Zava, Jirgba, & Osunkunle, 2017).

The last is a cross-section. Cross-sections on the road are designed depending on the location of the road, road function, class of road use, specifications for providing road infrastructure, and others. The proper design of the cross-section of the road is critical because of its impact on the facility's safety, capacity, and functioning. Although assessing the impact on its capacity and functioning is generally easy, it takes work to evaluate safety (Ministry of Public Works and Public Housing of the Republic of Indonesia, 2021); (Khattak, et al., 2021).

AutoCAD Civil 3D®

Before the existence of planning using programs, road planning using manual methods was often used. However, if there are errors or changes in its implementation, the modeling must be corrected manually. Therefore, a computer program is used to overcome it. One of the programs is AutoCAD Civil 3D®. AutoCAD Civil 3D® is a software application used by civil engineers and professionals to plan and design projects for the construction of buildings, road engineering projects, and water, including ports, canals, embankments, etc. (Mandal, Pawade, & Sandel, 2019).

One of the uses of AutoCAD Civil 3D® is to plan the geometry of the road. AutoCAD Civil 3D® is often used for design and drafting, so it can reduce the time required to change the design of tools and evaluate various situations. In addition, the program also provides a means of collaborating, so road modeling can be done in a team without any miscommunication. Collaboration can be done even if the team members are in separate places because the collaboration can be done using the internet network. The many features in AutoCAD Civil 3D® (Mandal, Pawade, & Sandel, 2019) make the road design process more efficient, accurate, and timesaving than designing roads manually (Pandey, Atul, & Bajpai, 2019).

Another plus of the AutoCAD Civil 3D® program is that it can perform design updates faster with intelligent 3D model-based applications, which dynamically update design elements as changes are made. So, problems that occur when designing geometric roads can be answered with this program. In addition to the advantages, this program has disadvantages, one of which is that the device specifications must be adequate. If not, the program will run slower, hindering the work. Furthermore, the system needed to install AutoCAD Civil 3D® is a device with a 2.5–2.9 GHz processor and 8 GB of RAM. So, it costs extra to buy a device, not to mention the cost of purchasing an application which is quite expensive. However, all these shortcomings can be covered by the advantages of this program (Autodesk Inc., 2022).

Geometric planning with AutoCAD Civil 3D®

The road design in this journal will use AutoCAD Civil 3D®. The reason is that the use of AutoCAD Civil 3D® for the geometric design of highways makes the design process completed concisely and efficiently and produces models with extraordinary precision. This capability of AutoCAD Civil 3D® eliminates the main disadvantages of complicated, time-consuming, and highly error-prone manual design. In geometric design using AutoCAD Civil 3D® (Raji, Zava, Jirgba, & Osunkunle, 2017), several data are needed, namely topographic data and traffic volume count data (Mandal, Pawade, & Sandel, 2019).

Topographic data can be retrieved from applications of LiDAR technology. Today, LiDAR is one of the most modern technologies used to survey and develop topographic maps for various purposes. The technology is based on the collection of three different data sets. The position sensor is determined using the Global Positioning System (GPS), and relative kinematics is measured by the phase measurement method using the Inertial Measurement Unit (IMU). LiDAR applications can retrieve data such as latitude, longitude, elevation, and other measurement data (Mijić, 2018); (Mandal, Pawade, & Sandel, 2019).

A traffic volume survey is a study to determine road vehicles' number, movement, and classification at any given time. Survey exercises are essential to the relevant authorities. The survey results will be used to plan and design traffic facilities, estimate road usage and traffic trends, and measure current demand to determine priorities for road upgrades and expansions. For this reason, an accurate estimate of traffic volume is significant. In addition, the number of passing vehicle volumes is needed to determine the number of lanes and road widths, design pavements, as well as to conduct a survey analysis of the economic impact on the roads built (Kadim, Johari, Samaon, Li, & Hon, 2020); (Mandal, Pawade, & Sandel, 2019).

With both data, modeling can be done using AutoCAD Civil 3D®. After the modeling is done, the results can be seen. The output produced by road planning using AutoCAD Civil 3D® is the design of horizontal alignment, vertical alignment, road assemblies, and road corridors. The result raised by AutoCAD Civil 3D® can be working drawings, analysis data, road profile drawings, and road cut drawings (S, J, Vishwas, & R, 2021). The image can be used as a benchmark in carrying out road construction.

METHOD

This Horizontal Alignment plan will be located near the Wahau estuary axis road in Sangatta Utara, East Kalimantan. The road will go to KPC Tanjung Bara (coal port), approximately 6.7 km from the Wahau estuary axis road. In addition to the port, the road is close to Tanjung Bara Airport and Tanjung Bara Housing. To get to KPC Tanjung Bara, a road can support the load from trucks carrying coal loads.

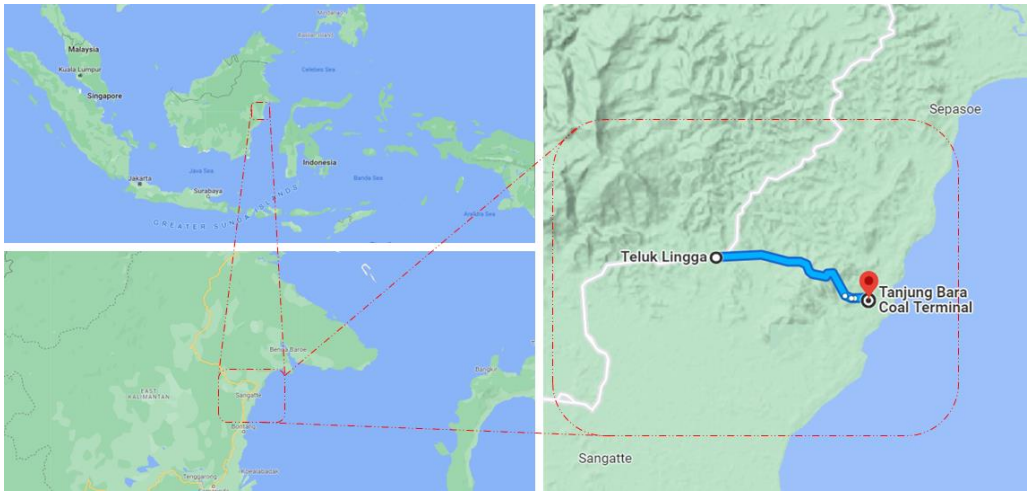


Figure 1. Road planning location

The systematic scientific research process must begin with identifying the right problem. In conducting this research, data is one of the leading forces in compiling scientific analysis and modeling. The data used in this report are classified as secondary data. The reason is that the data is obtained through google earth and global mapper. Secondary data analysis is the application of theoretical knowledge and conceptual skills in utilizing existing data to answer research questions (Rifai, Hadiwardoyo, Correia, & Pereira, 2016); (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, 2015); (Johnston, 2017).

In addition, qualitative research methods will be used in this study. Qualitative methods are expressed in natural language, while quantitative works are represented in numbers and statistical models. Furthermore, qualitative work uses a small sample, while quantitative work is based on an extensive N analysis. Because this study data from Google Earth and the global mapper will be analyzed using AutoCAD Civil 3D® (Gerring, 2017)®, the research of this journal will use qualitative methods.

RESULT AND DISCUSSION

The road data needed in the design of horizontal Alignment on Jl. Muara Wahau can be seen in Table 1.

Table 1. Data of Jalan Muara Wahau

Road Data	
Location	Jl. Muara Wahau, East Kalimantan
Road Status	National Roads
Road Classification System	Primary Arterial Road
Classification of roads based on the specifications of road infrastructure provision	JRY
Classification of roads based on-road use	Class I
Road Terrain	Flat (Terrain slope <10%)

Road Data	
Road Configuration	4/2 T
Design Speed (V_D)	70 km/h
Lane Width	3.5 m
Road Land Width (Rumaja)	21 m
Overall Width Between Building Lines (Rumija)	25 m
Overall Width Between Control Lines (Ruwasja)	15 m
Lane Width	3.5 m
Inner Shoulder Width	0.75 m
Outer Shoulder Width	2 m
Median Width	2 m
Normal Superelevation	2 %
Shoulder Superelevation	5 %
Maximum Superelevation	8 %
Maximum Slope	5 %

Horizontal Alignment Planning

After the road data is obtained, horizontal alignment modeling can be carried out on the Muara Wahau road, North Ssangatta, East Kalimantan. The steps performed in the planning of horizontal alignment using the AutoCAD Civil 3D® program are:

1. Retrieving topographic data.
   Used several websites and applications to retrieve topographic data. The website used is the DEMNAS website. Its function is to download TIF format topographic files in the Indonesian area. In addition, the Google Earth application is also used to mark area boundaries, old traffic, and points to be connected. The output file of the google earth application is KMZ. Next, both files are imported into the global mapper. The global mapper will process the file, producing a DWG-formatted topographic image. After that, the file can be accessed through the AutoCAD Civil 3D® application.

2. Drawing Trase Roads
   Road traffic is needed in road planning. Therefore, the trace is drawn according to the topographic plane that has been inputted. At first, the trace was drawn without using an arch (Curve). Below is the trace used in geometric road planning.

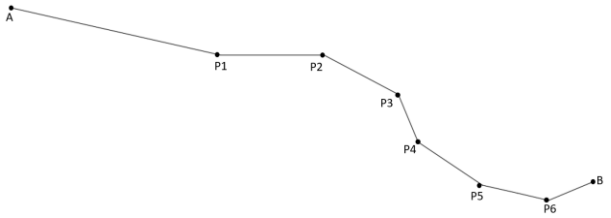


Figure 2. Route plans

Then, through the trace, a cross-section is made to determine the terrain classification based on the trace. Data from transverse chunks can be exported into excel, and then the data is calculated. According to the data obtained, the road trace is on a flat plane because, at every 50 meters distance, the slope is less than 10 percent. Here is a profile picture of the road.

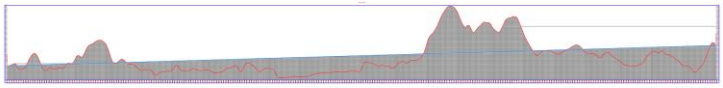


Figure 3. Profile view plans

Therefore, a road with a planned speed of 70 km/h is planned and a maximum superelevation of 8%. Then the two data are inputted into the modeled trace. Then in the next step, calculations for horizontal alignment curvature will be discussed. In the next horizontal alignment planning, the bend used is the bend located in P2.

3. Determining Horizontal and Superelevation Alignment Data

In modeling horizontal alignment and superelevation diagrams on AutoCAD Civil 3D®, data on the radius of the arc of circles and superelevations are required. Therefore, calculations are needed to determine these data.

a. Initial data required

Table 2. Data for road calculations

Road Calculation		
V (Design Speed)	70	km/h
e_{max} (Maximum Superelevation)	8	%
f_{max} (maximum transverse errors)	0.15	
β	27.67	º
e_d (Maximum Relative Slope)	0.55	
w (One Lane Width)	3.5	m
n_1 (Number of rotation paths)	2	
b_w (Adjustment Factor)	0.75	
m_{max} (Maximum Equivalent Relative Slope)	182	

$$R_{min} = \frac{V^2}{127(e_{maks} + f_{maks})}$$

$$R_{min} = \frac{V^2}{127(e+f)} = \frac{70^2}{127(8\% + 0{,}15)} = 167{,}75\ m$$

The R (Radius of the circular arc) worn must be greater than R_{min} (167.75 m). Therefore, a bend radius of 600 meters, e (super pavement elevation) of 4.3, and Ls min (Minimum length of intermediate arch run-off) of 41 meters were obtained. All three data are taken from Table 5-23. Relationship of LS (run-off) with VD (=Vr), for R, en=2%, emax=8%, on roads with lane width=3.50 meters from Highway Design Standard of Indonesia 2021 page 105.

b. Calculation formula

After the initial data has been calculated, it can be used to calculate horizontal alignment. The following are the formulas used in horizontal alignment modeling and superelevation diagrams:

Ls min 1 (Table) = 41 meters

$$L_s\ min\ 2 = \frac{w.n_1.e_d}{\Delta}(b_w) \quad \text{..... (1)}$$

w = Width of one lane of traffic

e_d = Design superelevation rate (%)

n_1 = number of rotated paths

b_w = Adjustment factor for the number of rotated paths

$$L_s \min 3 = \frac{0{,}0214\ .\ V^3}{R\ .\ C} \quad \text{..... (2)}$$

C = maximum rate of lateral acceleration change $(1{,}20\ m/s^3)$

$$L_s \min 4 = \sqrt{24\ .P_{min}\ .R} \quad \text{..... ..... (3)}$$

P_{min} = Minimum lateral offset distance between straight section and circular arc (0.20m)

Check whether the arch is the full circle or spiral circle spiral (SCS); by the way, if,

$$p = \frac{{L_s}^2}{6.\ R_c} \geq 0{,}25\ m, maka\ tikungan\ termasuk\ tipe\ SCS \quad \text{..... (4)}$$

$$\theta_s = \frac{90\ L_s}{\pi\ R_c} \quad \text{..... .... (5)}$$

$$\theta_c = \beta - 2.\Theta s \quad \text{..... (6)}$$

$$L_c = \frac{\theta_c}{360} 2.\pi.R \quad \text{.. ..... (7)}$$

$$p = \frac{{L_s}^2}{6.\ R_c} - R_c(1 - Cos\ \theta_s) \quad \text{... .... (8)}$$

$$E_s = \frac{(R_c + p)}{\cos\frac{1}{2}\beta} - R_c \quad \text{..... (9)}$$

$$\text{k} = L_s - \frac{{L_s}^2}{40.{R_c}^2} - R_c.sin\theta_s \quad \text{..... (10)}$$

$$T_s = (R_c + p)\tan\ (1/2\beta) \quad \text{. ..... (11)}$$

$$X_s = L_s\left(1 - \frac{{L_s}^2}{40.{R_c}^2}\right) \quad \text{..... (12)}$$

$$Y_s = \frac{{L_s}^2}{6.R_c} \quad \text{. ..... (13)}$$

c. Calculation Results

Through the formula calculation formulas listed in the section above, this bend includes the Spiral Circle Spiral (SCS) bend with the following data:

Table 3. The calculation results from the formula above

Calculation results		Code
$L_s\ min$ 1(m)	55	
$L_s\ min$ 2(m)	41.05	(1)
$L_s\ min$ 3(m)	10.19	(2)
$L_s\ min$ 4(m)	53.67	(3)
$L_s\ min\ Desain$(m)	119	
Θs (°)	5.68	(5)
Θc (°)	16.31	(6)
Lc(m)	170.87	(7)
p (m)	0.988	(8)
Ice (m)	18.945	(9)
k (m)	59.5	(10)
Ts (m)	207.506	(11)
Xs (m)	118.883	(12)

Calculation results		Code
Ys (m)	3.934	(13)
Run out (m)	55.349	

d. Inputting calculation results into AutoCAD Civil 3D®

After the data is obtained, the data can be inputted into the trace in the AutoCAD Civil 3D® application. Then, click the geometry editor and free spiral-curve-spiral for S-C-S arch modeling. Next, click the two trace lines you want to model and input the bend radius (R) and length of the spiral (Ls). After inputting the data, click enter, and the bend will be modeled as shown below.

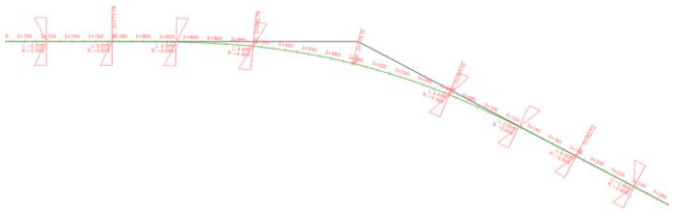


Figure 4. The horizontal alignment of the road at point P1

Once the bends are modeled, the superelevation diagram can also be raised. Therefore, by clicking on the trace of the road, then clicking calculates / edit superelevation. Furthermore, fill in the data according to the planned path, including run-out and run-off data. If all the data has been inputted, click finish, and click any place to put the superelevation diagram drawing. Figure 3. 4 is the result of a superelevation diagram.

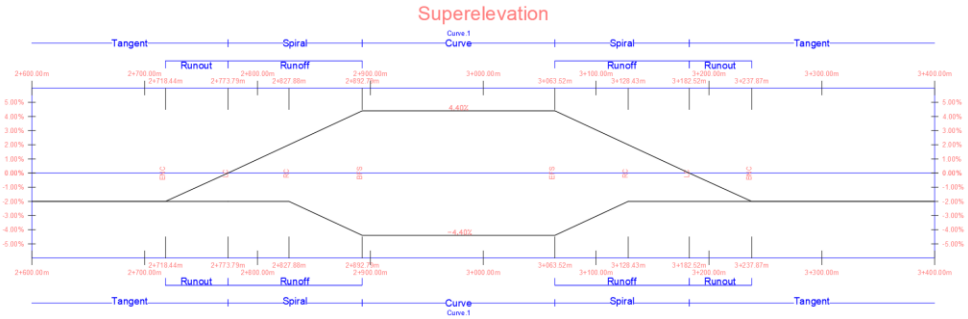


Figure 5. Superelevation diagram at point P1

CONCLUSION

Based on the results of the horizontal alignment planning that has been carried out, the author can conclude that the length of the road section is 6,086 km or 6086 m (STA.0 + 000 - 6 + 086). On the road, a bend with a point P1 on (STA 2+680 – 3+260) can use a bend with type S-C-S. Then, the R used on the road is 600 meters, e is 4.3%, and Ls is 119 meters. During the research, the author felt that the AutoCAD Civil 3D® program was beneficial in the research process, starting

from elementary traffic planning to the depiction of superelevation diagrams carried out automatically by the AutoCAD Civil 3D® ®® program.

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